Lossy Compression in Nuclear Medicine Images

Marina S.Rebelo, MSc
Sérgio S.Furuie , PhD
Agda C.L.Munhoz, MSc
Lincoln Moura, PhD
Candido P.Melo, MSc
InCor - HCFMUSP - São Paulo - Brazil

ABSTRACT

The goal of image compression is to reduce the amount of data needed to represent images. In medical applications, it is not desirable to lose any information and thus lossless compression methods are often used. However, medical imaging systems have intrinsic noise associated to it. The application of a lossy technique, which acts as a low pass filter, reduces the amount of data at a higher rate without any noticeable loss in the information contained in the images. We have compressed images of nuclear medicine using the discrete cosine transform algorithm. The decompressed images were considered reliable for visual inspection. Furthermore, a parameter was computed from these images and no discernible change was found from the results obtained using the original uncompressed images.

INTRODUCTION

The digital representation of images requires a very large number of bits. The increase in the use of imaging techniques in medicine and the advent of Picture Archiving and Communication Systems (PACS) have raised the issue of compression in medical images. The aim of compression techniques is to reduce, as much as possible, the size of files representing images in order to both save storage space and transmit efficiently.

Lossless compression methods permit the complete recover of the original image. The application of such methods typically reduces the amount of data by a factor of 1.5 to 3.0. Lossy methods can reduce the amount of data by a factor of ten or more, but the decompressed image may present some distortion relative to the original [3].

Ideally, no information should be lost in medical images as this might affect the diagnostic obtained from the images. However, as the physical processes acting on acquisition of medical images have noise associated to it, the lossless compression of these images stores pixel values with an accuracy beyond the signal-to-noise specifications of medical imaging devices [3]. The use of lossy methods that act as low-pass filters may be an alternative in which it is possible to achieve a higher reduction on image file size, still preserving all important information. Unfortunately, low-pass filters often remove edge information and some small structures. Therefore, the application of such methods to medical images must be very carefully assessed.

In this paper we will show that the use of a certain degree of lossy compression methods on nuclear medicine images allows high compression rates without any noticeable change in both visual inspection and parameter calculation.

METHODS

Compression technique

The lossy compression method used was the discrete cosine transform (DCT), which has been proposed by JPEG (Joint Photographic Experts Group - an international committee for establishing a compression standard for continuous-tone still images) as a compression standard for images [4]. The aim of transform-based compression methods is to eliminate redundant information on images which are more noticeable through some domain transformation. Describing the original data as a sum of cosine functions, the discrete cosine transform is a classical transform used in this scope. A complete formulation of the discrete cosine transform is found in reference [1].

The output of the DCT is a matrix of coefficients corresponding to the cosine amplitudes of all frequencies present in the image. No compression is achieved if all coefficients are coded. Medical images, however, have large homogeneous regions. So, many of the higher-order spectral components will be small and may either be coded with very few bits or deleted completely. For compression, it is possible to define some threshold above which the coefficients are deleted.

In this work the threshold has been defined as a percentage of the mean energy of the image. It is conventional to consider the squared value of an image element (pixel) as a measure of the energy it contains. The mean energy of the image is the summation of the energy of all pixels divided by the number of pixels.

Acquisition and processing of images

The compression method was applied to cardiac nuclear medicine images. The study chosen for the analysis was gated blood pool imaging. The images were acquired by a Siemens Gamma-Camera located at the Nuclear Medicine Department of São Paulo Heart Institute - FMUSP.

The phenomenon of interest in gated blood pool imaging is the volume change of the left or the right ventricle. After the cardiovascular blood pool is labeled with an appropriate radionuclide, the time variations of the ventricular volume are sampled with high temporal resolution. Human serum albumin (HSA) labeled with Tc-99m can be administered, or the red blood cells (RBC) can be tagged with Tc-99m using in vivo techniques [2]. The entire cardiac blood pool is imaged at various time instants in the heart cycle. Successive heart beats are added until an adequate count density is reached for statistically reliable analysis.

Each gated blood pool study contains a sequence of 32 images which have been acquired synchronized with the patient's ECG. After acquisition, images are digitized on a 64 x 64 pixel matrix with a 16-bit depth resolution and processed on a MicroVax 13300 computer.

One of the most important parameters computed from the set of 32 gated blood pool images is the left ventricle ejection fraction, which is defined as:

$$EF_{lv} = \frac{C_{Dlv} - C_{Slv}}{C_{Dlv}} * 100\% \qquad (1)$$

where:

C_{Dlv} is the total count inside the left ventricle at diastole;

C_{Slv} is the total count inside the left ventricle at systole.

It is assumed that for normal hearts the values of ejection fraction are greater than 55%.

The compression algorithm was implemented in C on a VAX 6420.

Analysis

Initially, a few sequences were visually inspected to determine the upper level of compression for which the images were still reliable for diagnosis. The images were compressed with threshold coefficient values of 10, 20, 30, 40 and 50% of the mean energy. In the inspection, a physician analized the sequence of 32 images before and after the application of the compression algorithm. The objective was to look for differences in morphology and blood flow in cardiac chambers

The compression algorithm (with the threshold set to the chosen value) was then applied to a group of 23 normal heart sequences. The ejection fraction was computed before and after compression. The results are presented later in this paper.

The measure of compression presented here is the compression rate which is given by the number of bytes needed for representation of the original image divided by the required for the compressed one. In fact, as we are dealing with sequences of 32 images we calculate the value for the sequence as a whole, that is, the number of bytes of the original sequence divided by the number of bytes needed after compression.

RESULTS

The compression time ranged from 2 to 3 seconds per image. Decompression took approximately 1 second.

The images compressed with a threshold up to 30% of the mean energy were considered reliable for visual inspection.

The EF values and the compression rate obtained for the 23 gated blood pool studies compressed with the threshold value of 30% of the mean energy are presented on Table 1. Besides, both absolute and percentage differences between ejection fraction before and after compression are presented.

number of study	EF before compression (%)	EF after compression (%)	Absolute difference	Percentage difference (%)	Compression rates
1	58	59	1	1.7	15.4 : 1
2	61	60	1	1.6	11.4 : 1
3	55	57	2	3.6	15.7 : 1
4	55	53	2	3.6	13.7 : 1
5	63	59	4	6.3	11.1 : 1
6	65	63	2	3.1	11.2 : 1
7	68	65	3	4.4	10.8 : 1
8	54	52	2	3.7	20.0 : 1
9	63	59	4	6.3	10.8 : 1
10	62	58	4	6.4	13.1 : 1
11	71	68	3	4.2	11.6 : 1
12	70	68	2	2.8	11.1 : 1
13	74	73	1	1.3	11.8 : 1
14	83	76	7	8.4	11.2 : 1
15	66	65	1	1.5	11.2 : 1
16	65	65	0	0	10.7 : 1
17	56	55	1	1.8	10.5 : 1
18	65	58	7	10.7	14.3 : 1
19	75	67	8	10.6	13.6 : 1
20	65	71	6	9.2	15.1 : 1
21	69	72	3	4.1	14.2 : 1
22	63	62	1	1.5	10.8 : 1
23	55	52	3	5.4	14.0 : 1

Table 1 - Values of computed ejection fraction for the 23 sequences of normal hearts before and after compression are presented in the 2nd and 3rd columns, respectively. The absolute difference between EF before and after compression is presented in column 4. In column 5 the percentage difference (absolute difference divided by EF before compression, multiplied by 100%) is presented.The compression rates are presented in column 6.The compression method used was the discrete cosine transform (DCT) and the threshold above which the coefficients were deleted was set to 30% of the mean energy of the image

The analysis of Table 1 shows that except study number 4 computed ejection fraction values remain within the range of normal heart values. It should be pointed out that compressed image calculated parameters in this case are comparable to the same values calculated from uncompressed images. Another important point is image count rate. The images acquired with low count rates led to higher differences both relative and absolute.

The values of EF before and after compression were analyzed by the Wilcoxon test and no significant difference was found between the two groups, which means that the data were acquired from two indistinguishable sets of images.

In Figure 1 we present an image of a gated blood pool sequence before and after compression with the threshold set in 30% of mean energy

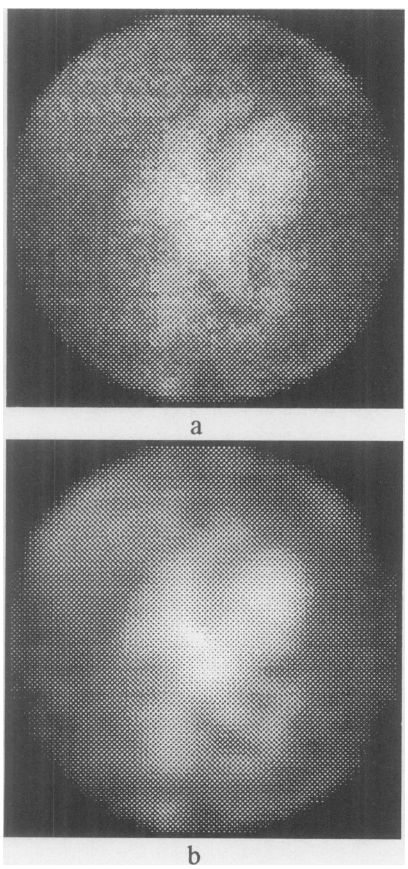

Fig. 1 - Image of a gated blood pool study: (a) original and (b) after compression.

DISCUSSION AND CONCLUSION

As we were essentially interested in the analysis of the quality of decompressed images, the compression/ decompression times were not optimized.

A visual noticeable change on the decompressed images is the smoothing due to aliasing produced by truncation of the coefficients from discrete cosine transform, which can be observed in Figure 1. This effect becomes more severe as the threshold for the truncation of coefficients is raised. Above a certain value, the distortions introduced in the images make them unacceptable for diagnostic analysis. For the images used in this work, the upper threshold for which image quality was considered suitable was 30% of mean image energy. The visual inspection showed that analysis of morphology and dynamics of the heart did not change on the sequences after the application of the compression algorithm with the threshold set up to that value.

Since ejection fraction is usually computed from a manual digitization of the left ventricle contour, it is dependent on the operator. For most of the sequences, however, the differences in EF before and after compression were of the same order of differences of those obtained between different operators. The statistical analysis of the values obtained for the EF showed that the application of the compression method produced sets of images indistinguishable from the originals. Again the careful determination of the truncation value is very important. If an excessive smoothing was produced by the application of the algorithm, the computation of EF could yield to false results since the smoothing could cause an erroneous edge detection of left ventricle on the entire sequence of images.

The present analysis showed that the application of a lossy compression method in nuclear medicine images can produce decompressed images suitable for diagnosis with rates that ranged from 10.8 : 1 to 20.0 : 1.

ACKNOWLEDGMENT

The authors thank Ms. Creusa Dal Bó for the statistical analysis of the data.

REFERENCES

[1].R.J.Clarke. Fast Transform and System Implementation in Transform Coding of Images. London, Academic Press, 1985.

[2].M.J.Gelfand; S.R.Thomas. Equilibrium Gated Blood Pool Imaging at Rest and During Exercise in Effective Use of Computers in Nuclear Medicine. McGraw-Hill Book Company, 1988.

[3].B.Shih-Chung; B.Krasner,B. & S.K.Mun. Noise Impact on Error-Free Image Compression. IEEE Transactions on Medical Imaging,9(2):202-206,1990.

[4].G.K.Wallace. The JPEG Still Picture Compression Standard. Communications of the ACM, 34(4):31-44,1991.